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SURFACE DRAINAGEOF LOWLAND RICE IN KUSHBHADRA-BHARGAVI DOAB IN ORISSA - A CASE STUDY

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AUTHORS

ABSTRACT

Adoption of suitable methods of cultivation and surface drainage are the two methods which could facilitate cultivation of rice in low lands. Keeping the stochastic hydrograph of ponding in view, cultivation methods like selection of low land rice varieties, dates of seeding/ transplanting are practised. The modification of rice ecosystem is affected by modulating the depth and duration of ponding which is achieved through surface drainage.

A network of ditches constructed by the Government of Orissa during 1991 has increased the drainage density in Kushbhadra-Bhargavi doab from 0.51 km/sq.km to 0.78 km/sq.km. The study revealed that the surface drainage has modified the rice ecosystem by reducing depth and duration of ponding, thereby decreasing the risk of Kharif paddy production. It induced the farmers to practise improved methods of rice production by adopting high yielding varieties and enhanced use of chemical fertilizers. Surveys in the catchments of ditch number 14 and ditch number 16B during 1992, just after the construction of the drainage network, has revealed an increase in paddy yield by 29 and 34 percents, respectively. The cropping intensity has also registered marginal increase of 5.24, and 2.85 percents, respectively. It is recommended that the maintenance of drains should initially be performed by the government till there is substantial increase in cropping intensity which would induce the beneficiary farmers to realise the advantage of surface drainage in improving their crop production. Later, after the realisation, the maintenance work needs to be handed over to the farmers organisations.

INTRODUCTION

Topographically and agro-hydrologically the rice lands are divided into three broad categories, viz., uplands, medium lands, and low lands. The classification of rice fields is based on relative elevations which in turn determines the depth and duration of submergence of these lands during a year. For example, out of the total cultivated are of 64.67 lakh ha in orissa, about 46.54 % is uplands, 29.34 % is medium lands and 23.61 % is low lands (Anonymous, 1992). The saucer shaped lands in a tract are lowlands where runoff and seepage water of the tract accumulates. The rising surface water levels of many isolated lowlands join along a shallow natural depression and form a seasonal stream. The water from such a stream ultimately flows to a river system. The lowlands are also flanks of the natural drainage ways where runoff water accumulates.

Farmers primarily grow rice during monsoon season in several canal irrigated tracts and high rainfall areas of the country. The lowland rice crop often faces the moisture stress due to excess water which not only submerges the land but sometimes the crop as well. The rainfed lowland rice occupies about 20.5 M ha (CRRI at a glance, 1992) which is prone to waterlogging of various depths. Based on depth of ponding the rainfed lowland rice ecosystem has been broadly classified into four categories. Water stagnation upto 30 cm is termed as shallow lowland, upto 30 to 50 cm as intermediate lowland, upto 50 to 100 cm as semi-deep low land, and more than 100 cm as deep water low land. Low lying rice lands are located in eastern Uttar Pradesh, Bihar, West Bengal, Orissa, Assam, Manipur, Tripura, Andhra Pradesh, Tamilnadu, Kerala, costal Karnataka and Maharashtra. Under natural condition, the average yield from such lands is about 1.3 tonne/ha. In high rainfall areas the irrigated rice crop may suffer from waterlogging during Kharif season due to ill drained conditions.

STRATEGIES FOR RICE PRODUCTION IN THE LOWLANDS

The hydrograph (depth versus time) of ponding in the lowlands is related to the rainfall pattern, physiography, soil type, and drainage characteristics of the area. Since the occurrence of rainfall is a stochastic phenomenon, the hydrographs of the lowlands is also stochastic. Consequently, the depth, duration, and frequency of submergence of the lowlands is quite uncertain. Rice is the only cereal crop in these lands that could be grown by adopting suitable methods of cultivation and drainage.

The cultivation method include (1) selection of lowland rice varieties (2) transplaanting at appropriate age of rice seeding, (3) selecting rice varieties which could tolerate few days of submergence, and (4) selection of seeding/transplanting date keeping hydrograph of ponding in view. Thus surface hydrology in conjunction with rice cultivars are the most dominant factors for rice cultivation in the lowlands.

Some of the hydrologic situations that are likely to be encountered in the lowland rice cultivation are (1) limited water during seeding stage and excess water at latter growth stages of crops; (2) excess water at transplanting as well as latter growth stages; (3) excess water during intial period and less water during latter growth periods; and (4) lowland rice fields in which the nature of flash floods is stochastic. In all the aforementioned four hydrologic situations the rice yields would be affected by the depth and duration of ponding in relation to the crop growth stages.

(i) Surface Drainage for the Modification of Lowland Rice Ecosystem

The purpose of surface drainage is the orderly removal of excess water from the fields to provide favourable edaphic environment for crop growth. It is achieved through improved natural channels or constructed ditches at the level of the watershed. However, shaping of the land surface hastens the removal of excess water at the micro field level. Surface drainage system accelerates flow to an outlet without siltation and erosion of soil, and reduces depth and duration of ponding when it is designed properly. It prevents prolonged saturation and thus facilitates the timely preparation of lands for subsequent crops. In order to design the drainage system it is necessary to demarcate the areas of lowlands and valleys where submergence due to precipitation, seepage, irrigation, or sea water inundation have substantially reduced crop yields. Once the target area is identified, the following steps are helpful in designing the surface drainage system.

1. Preparation of detailed topographic map to demarcate areas at different elevations, and watershed boundaries.

2. Location of a natural outlet to drain excess water from the lowlands.

3. Measurement/development of spatial and temporal distribution of ponding in the lowlands and at the outlet point in the natural drainage way.

4. Determination of temporal differences in the water levels of the lowlands and the outlet point.

5. Demarcation of the main and submain surface drains on the topographic map.

6. Identification of the watershed areas for different segments of the main and submain drains.

7. Estimation of rainfall excess and its rate of removal (available for drainage) at different points of the proposed drains.

8. Determination of drain cross section and slope for different segments of the proposed drainage network.

The topographic map should be detailed enough to precisely estimate area of submergence at different water levels. The proposed drain should pass through the low lying areas to the outlet. The determination of drain slope and cross section involves detailed hydrologic computations and hydraulic design. Each design will yield a set of spatial hydrographs of ponding in the lowlands, which may modify an intermediate lowland into a shallow lowland, a semi-deep into an intermediate, and a deep water into a semi-deep water lowland ecosystem. The change may not occur in a single step alone; it may occur in two or more steps, and under very unfavourable situations a deep water ecosystem may remain deep itself. The hydrograph of ponding at a few selected points of the lowland and estimated cost of construction of the drain and associated structures should be determined for different drain designs. Finally, out of several plausible designs, one should select the one that is economical and which optimally modifies the lowland ecosystem in large area of the tract for higher crop production.

PERFORMANCE EVALUATION OF SURFACE DRAINAGE PROJECTS

In assessing the performance of a surface drainage projects, it is necessary to evaluate the changes in hydrologic regime and its impact on crop production. The adequacy and ecofriendliness of the new hydrologic regime, its helpfulness in timely and preparation, land its usefulness to crops are the related issues which should be considered while evaluating the performance of the projects. In high rainfall deltaic areas, a scientifically planned and well executed surface drainage project not only protects the crops but also reduces damage to raods, buildings, and communication networks. It improves general environment, thereby eliminating the occurrence of flood induced diseases and loss of lives. These parameters could be made performance indicators. Economic analysis, on the other hand, is generally confined to determining the economic rate of return of all the resources committed to the project, regardless of who finances the project and who benefits from it. In the proposed case study we present the performance evaluation of ditch number 14 and 16B, the two ditch drains belonging to the drainage network constructed in the tract lying between Kushbhadra and Bhargavi rivers in Orissa. Only the hydrology of the catchment, adoption of high yielding varieties of rice, use of chemical fertilizers, and rice production have been taken as measures of performance evaluation.

SURFACE DRAINAGE IN KUSHBHADRA-BHARGAVI DOAB

Figure 1 (Engineer-In-Chief, 1989a) shows a tract of land in the state of Orissa, lying between Kushbhadra and Bhargavi rivers which on an average receives 1572 mm rainfall annually. The total geographical area of the doab (land between two rivers) upto the Bay of Bengal is 803.75 sq.km out of which 280 sq.km is the culturable command area of the canal network in the doab. About 112 sq.km area suffers from serious waterlogging during wet (monsoon) period (Plate 1), including some area that is waterlogged during summer months. Before construction of surface drains, in many low lying depressions, there was no cultivation even during dry season. During 1990-92, the Govt. of Orissa has constructed a network of main and sub-main drains (Fig.1) connecting lowland depressions to natural drainage system. The execution of the drainage plan has increased the drainage density of the doab from 0.51 km/sq.km to 0.78 km/sq.km. (Engineer-In-Chief, 1989b). This drainage network has modified the hydrograph of ponding as revealed by the farmers in personal conversations.

The Water Technology Centre for Eastern Region (WTCER) undertook a survey during 1993 to study the changes in production scenario during Kharif (June to November) of 1992 in the catchment of drain number 14 and 16B (Fig.1). Drain number 14 is 5.28 km long and crosses Pipili-Konark road in the middle of approximately 9 km wide tract lying between rivers Dhanua and Kushbhadra, whereas, the drain number 16B is 3.048 km long and falls in Mugei drainage channel (Plate 2). Ditch 14 drains a large tract of agricultural lowlands belonging to the villages Dhaleswar, Tala Andia, Hanspara, Dhenua, Dahijanga, and Ratila near Nimapara, Distirct Puri and the ditch number 16B drains a tract belonging to the villages Patapur, Kiankanta and Ghanti. The estimated catchment area of the ditch 14 is 7.28 sq.km. However the catchment area for ditch 16B is approximately 1.5 sq.km. The elevations of a stretch of one km land across point "b" and "c" marked at the drain 14, and point "a" marked at the drain 16B were determined employing dumpy level survey. The low land in both the sides of the two drains is almost flat with a very small longitudinal slope. Consequently, the ditch 14 and 16B have slope of 0.011 and 0.003 percents, respectively. On an average both the drains are about 8 m wide and 1.3 m deep from the top of the drain bund.

A farmers friendly questionnaire was prepared and a group of scientists and technicians personally met the farmers to fill the questionnaire to know the changes in cultivation practices and yield of rice as a result of construction of the drainage system. The scientists and technicians of the WTCER have collected information from 166 and 65 farmers covering an area of 210.81 ha and 116.79 ha in the catchments of drain number 14 and 16B respectively. The survey revealed that the surface drainage system has improved the rice ecosystem which has facilitated the adoption of improved production technologies like use of high yilding varieties and inorganic chemical fertilizers. It has resulted in enhanced crop yields. Some observed changes in sequential order are enumerated below.

(i) Modification of Rice Ecosystem

The original hydrograph of ponding is not available as it was not measured by the Department of Irrigation, Government of Orissa, prior to the installation of drains. However, the depth and duration of ponding, as reported by the farmers, has been modified making it more ecofriendly for rice crop. The degree of ponding , after the installation of the drainage network, has been measured by WTCER during the 1993 monsoon at two culverts in the vicinity of locations "b" and "c" along the link drain 14 and locations "a" along the drain no.16B (Plate 3). The relative elevation of any point in the agricultural fields in relation to the point in the drain where hydrograph has been measured helps in determining the hydrograph at the point in the field. Thus if point, "1", in the field is at E_1m above the drain point, "a", where the hydrograph is $h_a(t)$, then the hydrograph $h_1(t)$ at point, "1", is determined as below.

$$h_1(t) = h_a(t) - E_1 \qquad (1)$$

Equation (1) is based on the principle that a liquid achieves its own level, and hence the slope of the free water surface is neglected. This way one may determine the hydrograph at any point in the field near the point of measurement in the drain. The daily rainfall data for the monsoon months of July to September 1993 is depicted in Fig.2. The raianfall measuring station near Nimapara is approximately 4 km away from the middle of the catchment of ditch 14 and 16B. Hence the rainfall in the measuring station may sometimes be at variance with the true rainfall in the catchment. Two hydrographs at points "b" and "c" in drain 14 and one hydrograph at point "a" in drain 16B (deduced from the measurements at the near by culverts) are plotted in Fig.2.

The hydrographs $h_1(t)$ and $h_b(t)$ shown in Fig.2a are similar to $h_2(t)$ and $h_c(t)$ shown in Fig.2b. Hence only Fig.2b is described. Fig.2b depicts a maximum ponding depth of 1.24 m in the drain 14 on 15th July 1993 resulting from a rainfall of 158.4 mm on the same day.

During the monsoon of 1993 the water level remains above one m for first to forth July, 15th to 21st July, and 5th and 6th August 1993. For all other days it remained below 1 m in the drain. The flow in the drain continues for the entire period of measurement, i.e., till the end of September. When water level in the drain remained above 1 m, it achieved a ponding depth of more than 0.2 m in the cropped field at point "2" (70 m away from the left bank of the drain) as is clear from the hydrograph $h_2(t)$ in Fig. 2b. Thus it remained above 0.2 m for first to fourth July, 15th to 21st July, and 5th and 6th August 1993. The water level in the field achieved a maximum height of 0.45 m on 15th July.

The hydrograph $h_a(t)$ at point "a" of drain 16B (Fig.2c) reveals a maximum ponding depth of 1.115 m in the drain on 5th August resulting from rainfall of 52.4 mm and 42.8 mm on 4th and 5th August 1993 and followed by 1.085 m depth of ponding on 17th July 1993. During that period, the water level remained above one m from 15th to 18th July, 4th to 6th August, 8th to 15th August and 19th to 22nd August 1993. For all other days it remained below 1 m in the drain. When water level remained above 1 m in the drain, it achieved, a ponding depth of more than 0.255 m in the cropped field at point "3" (150 m away from the left bank of the drain) as is clear from $h_3(t)$ in Fig.2c. The water level achieved a maximum depth of 0.365 m on 5th August. For long duration rice varieties, the hydrograph $h_1(t)$, $h_2(t)$ and $h_3(t)$

may be considered a favourable one during the year 1993. As the maximum ponding in the field is less than 0.5 m, the long duration high yielding rice which are about a metre tall could be very well cultivated by the farmers.

(ii) Adoption of High Yielding Varieties

The analysis of information collected from the farmers in the catchment of drain 14 reveals that around 84% and 2% of the sampled farmers were cultivating traditional and high yielding varieties of paddy respectively, before drainage. The remaining 14% were growing both the traditional and high

yielding varieties of paddy before drainage. The post drainage scenario is encouraging as around 69% of the respondents cultivated high yielding varieties and rest 31% cultivated local and high yielding varieties in the Kharif season. Not even a single farmer was growing local varieties after drainage. The commonly adopted HYV by the farmers after drainage were CR-1009, CR-1014, CR-1018, Lalat and Samalai.

The survey revealed similar trend in the catchment of drain 16B. Out of 65 farmers interviewed only 1% farmers were using HYV along with local varieties and rest were cultivating local varieties only. However the scenario after drainage had a drastic change in the variety of paddy, as about 88% farmers were using HYVs and 12% of farmers used local varieties along with HYVs. The commonly used local varieties before the drainage system were Mayurkanta, Bhutia, Kalabegunia, Chanda, Kalakhajura etc. The post drainage HYV varieties were CR-1009, CR-1014, CR-1018 and Samalai.

The hypothesis that the optimal soil water regime is a pre-requisite to the adoption of high yielding varieties is very well corroborated from this survey.

(iii) Use of Inorganic Chemical Fertilizers

Data was collected by the scientists and technicians of the WTCER from 166 farmers covering an area of 210.81 ha in the catchment of drain 14. Table 1 shows the use of chemical fertilisers and FYM before and after the installation of the drainage system size class wise in the catchment of drain 14. A perusal of Table 1 indicates that most of the farmers are marginal and small owning land below 2 ha. The size class of 2 to 4 ha has only 18% farmers and only 5% of farmers have land above 4 ha. Table 1 reveals that the farmers did not use any inorganic chemical fertilizers before drainage; they applied only FYM at an average rate of 2258.25 Kg/ha (i.e. 11.29 kg/ha Nitrogen, 4.52 kg/ha phosphorous and 11.29 kg/ha potash). The scenario after drainage shows a drastic change in the fertilizer use. After drainage, there is a decrease in the use of farmyard manure (564.47 Kg/ha, i.e. around 2.82 kg/ha Nitrogen, 1.13 kg/ha phosphorous, and 2.82 kg/ha potash) and a beginning is made towards the use of inroganic chemical fertiliser with an average rate of 180.33 Kg/ha.

Similarly information from 65 farmers covering an area of 116.79 ha were collected in the catchment of drain number 16B. The analysis of results are shown in Table 2. About 70 % of the farmers are small and marginal owning land below 2 ha. Here also the trend is similar to that of drain number 14. The farmers used only FYM before drainage with an average application of 3277.70 kg/ha (i.e., 16.39 kg/ha nitrogen, 6.55 kg/ha phosphorous and 16.39 kg/ha potash). However, after the installation of the drainage system there is a decrease in the use of FYM (1085.12 kg/ha i.e., 5.43 kg/ha nitrogen, 2.17 kg/ha phosphorous and 5.43 kg/ha potash) and application of organic chemical fertilisers have started with an average rate of 386.11 kg/ha. No detailed information regarding the quantum of inorganic nitrogenous, phosphatic, and potassium fertilizers have been collected from the farmers in the catchment of both the drains.

Table 1. Distribution of FYM/Fertiliser use (kg/ha) in the catchment of drain 14.

Sl. No.	Land holding (ha	No. of farmers	FYM/ Fertiliser Use			
			Pre drainage		Post drainage	
			FYM	Fertiliser	FYM	Fertiliser
1.	0.0-1.0	71	2442.50	0.0	1385.00	170.00
2.	1.0-2.0	56	2382.50	0.0	852.50	180.00
3.	2.0-4.0	30	2472.50	0.0	297.50	172.50
4.	4.0-10	7	2322.50	0.0	212.50	127.50
5.	>10.0	2	1332.50	0.0	0.0	257.50

Table 2. Distribution of FYM/Fertilizer use (Kg/ha) in the catchment of drain 16B.

Sl. No.	Land holding (ha	No. of farmers	FYM/ Fertiliser Use			
			Pre drainage		Post drainage	
			FYM	Fertiliser	FYM	Fertiliser
1.	0.0-1.0	21	3057.68	0.0	906.38	317.35
2.	1.0-2.0	24	3546.70	0.0	1759.45	409.33
3.	2.0-4.0	15	3293.60	0.0	585.05	321.98
4.	4.0-10	4	3362.08	0.0	45.35	501.35
5.	>10.0	1	2500.00	0.0	3000.00	375.00

(iv) Increase in Rice Yields

Average agricultural productivity of paddy before and after the installation of the drainage system is shown in Table 3. The table reveals that there has been an increase in average productivity of paddy from 14.52 q/ha to 18.80 q/ha i.e. 29.48 per cent in the catchment of drain no 14 after the construction of the drainage system. The increase in the class interval of 1 to 2 ha and 2 to 4 ha has been of the order of 37 and 29 percents, respectively.

Similarly, there has been an increase in average agricultural productivity from 22.19 q/ha to 29.65 q/ha i.e. 34 percent (Table 4) in the catchment of drain number 16B. The increase in the class interval of 0 to 1.0 ha and 2.0 to 4.0 ha is of the order of 57 and 47 percents, respectively.

As the drainage provided more favourable soil water regime the farmers have been induced to adopt high yielding varieties and to use inorganic chemical fertilisers. The drainage has changed the ecosystem of the area thereby creating a favourable condition for Kharif paddy. As the 1992 Kharif rice has been the second Kharif rice crop after the installation of the drainage system the increase in yield has been small. But it has created confidence amongst the farmers about the effectiveness of drains in modifying the rice ecosystem and alleviating submeregence of rice crops. It would help in realising the yield potential of long duration low land high yielding rice varieties.

Table 3. Distribution of Paddy yield (q/ha) in the catchment of drain 14.

Sl. No.	Land holding (ha)	No. of farmers	Reported area (ha)	Pre drainage		Post drainage	
				Cropping intensity (%)	Yield	Cropping intensity (%)	Yield
1.	0.0-1.0	71	29.70	99.62	15.95	105.80	18.68
2.	1.0-2.0	56	63.72	92.80	13.80	109.80	18.90
3.	2.0-4.0	30	58.46	90.56	17.90	103.40	23.05
4.	4.0-10	7	28.93	98.73	10.63	99.50	14.40
5.	> 10.0	2	30.00	54.81	11.83	19.43	14.70

A. Average yield before drainage system = 14.52 q/ha

B. Average yield after drainage system = 18.80 q/ha

C. Percentage increase in yield, (B-A)/A X 100 = 29.48 % $\simeq$ 29 %

Table 4. Distribution of Paddy yield (q/ha) in the catchment of drain 16B.

Sl. No.	Land holding (ha)	No. of farmers	Reported area (ha)	Pre drainage		Post drainage	
				Cropping intensity (%)	Yield	Cropping intensity (%)	Yield
1.	0.0-1.0	21	12.69	133.15	19.68	145.68	30.88
2.	1.0-2.0	24	33.54	134.55	21.23	140.96	25.38
3.	2.0-4.0	15	36.92	119.66	24.05	120.08	35.45
4.	4.0-10	4	22.44	121.25	26.80	118.40	29.35
5.	>10.0	1	11.20	117.86	12.50	126.09	22.50

A. Average yield before drainage system = 22.19 q/ha

B. Average yield after drainage system = 29.65 q/ha

C. Percentage increase in yield, (B-A)/A X 100 = 33.62 % $\simeq$ 34 %

(v) Timely Availability of Land for Second Crop during Rabi

One of the objectives of land drainage is the timely removal of excess water from the fields to make it ready for cultivation. This objectives has been fulfilled as the fields were free of water from November-December onward. The monsoon rice is harvested during November and December and thus land is available for subsequent Rabi crop. However, due to the lack of optimal irrigation facility during Rabi, most of the farmers keep their lands fallow; only a few having tubewells grow rice, pulses and other crops. Because of this the cropping intensity in the catchment of drain 14 and 16B have registered only a marginal increase of 5.24 and 2.85 percents, respectively.

SOME MANAGEMENT CONSTRAINTS

At the end of the monsoon when the flow recedes in the drains, the poor farmers dam the drains at frequent intervals to catch fish. This way they isolate the flow of water to a segment of the drain, remove water from the segment using manually operated water lifting devices, and then catch the fish present in the segment. Thereafter the dams remain intact creating obstruction to flow during the next monsoon season. This necessitates proper maintenance of the drains.

In personal conversations farmers complained the lack of maintenance of the surface drains. Plate 4 shows complete infestation of water hyacinth in drain 14. Thus it is suggested that initially the maintenance should be done by the government departments so that the farmers get all the advantages of drainage. Once they have started practising intensive cultivation, the maintenance of the drains should be handed over to the farmers' organisation.

LESSONS FROM THE CASE STUDY

Surface drainage has favourably modified the hydrograph of ponding, hence the soil water regime in the rice fields. It has acted as prime mover in creating favourable environment for the adoption of high rice production technology involving high yielding varieties of rice, and inroganic chemical fertilisers. The adoption has initiated the process of increase in rice yield.

Due to surface drainage, the land is free of excess water and is available for cultivation during the months of November-December. If irrigation facilities are developed, the farmers will go for second crops; thereby increasing the cropping intensity, crop production, and other benefits associated with agriculture.

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Measurement showing hydrograph of ponding in open drain

Infestation of water hyacinth causing reduction in carrying capacity of open drain

Complete submergence of low-land rice during rainy season

Surface drainage of low-land rice in Kush Bhadra-Bhargavi Doab, Orissa